# Components for 5G – What is new?

Markus Lörner, Rohde & Schwarz

## INTRODUCTION

With the next big step in mobile communication, 5G will introduce new RF techniques, new frequencies and signal bandwidths. Ultimately, 5G New Radio (5G NR) will bring higher speed, reduced latency, more capacity and improved reliability. While the system parameters will change, the hardware to enable the new major step in mobile technology towards 5G NR will be different as well. New technologies will be deployed and designs have to follow the new requirements. The baseline for this development will be new RF components with higher integration and efficiency.

## NEW REQUIREMENTS FROM 5G

The focus of 4G Long Term Evolution (LTE) was to increase data rate and throughput in forward and reverse link (downlink and uplink) in order to address the increasing hunger for more and faster data. While 4G is reaching its target of being able to transmit 1Gbit per second in the downlink, the next generation 5G is getting mature. The overall definition of 5G is following a new approach looking after various needs for mobile communication. The new standard addresses three major needs, also known as the "triangle of application". Enhanced mobile broadband (eMBB) is the known playground seeking for higher data rates. Massive internet of things (mIoT) is another big driver looking for low energy consumption and small data package transmissions. Ultra reliable and low latency communication (URLLC) is the third pillar for 5G for secure voice and data communication.

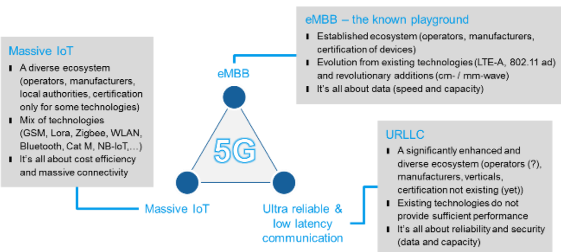


Fig. 1:5G applications triangle

To find enough frequency spectrum for highest data rate links, 5G will go all the way to microwave frequencies. 24 to 28 GHz and 39 GHz are targeted in many countries of deployment. The signal bandwidth will be significantly wider compared to 4G LTE. The standard supports various bandwidths up to 400 MHz per carrier, plus carrier aggregation similar to LTE. As wide area coverage at these high frequencies will be very challenging, 5G will use spectrum in the sub 6 GHz range, with 3.5 GHz as a common number around the globe. Carrier bandwidths for sure will be smaller sub 6 GHz; nevertheless, 100 MHz are included in the 5G standard for sub 6 GHz operations.

To enable low latency for URLLC and very small data packets for mIoT, the structure of the physical layer will be much more flexible. Network flexibility is the way forward. In the time axis, 5G offers flexibility in the duration of time slots through varying symbol rates. In the frequency range, "Bandwidth Parts" (BWP) are introduced to allow variance of the physical layer within one carrier signal. For mIoT, low battery consumption is a key topic. Just sending very short and small data packages helps already big times. In order to reduce the amount of power, which needs to be transmitted to connect from the IoT device to the grid, lower frequencies will be used. The lower the RF frequency, the lower the free field attenuation. 5G includes frequency bands below 1 GHz, which are meant for IoT devices helping them to reduce the amount of power to be transmitted to get the signal across.

5G shall be ramping up as quickly and early as possible to help network operators offering higher data rate to customers as early as possible. To do this, the first approach will be to keep relying on the 4G backbone and control handling between the base station and the user equipment. This means that a user equipment must be connected at the same time via 4G for receiving control information and via 5G to allow maximum throughput. Therefore, in the anyway limited space inside mobile devices, also one more system needs to be included and be run at the same time. This will generate per say a higher drain from the battery to support both links simultaneously.

The correlation between free field attenuation and RF carrier frequency helps reducing the output power for IoT applications at lower frequencies below 1 GHz, but is a challenge for mmWave frequencies. Generating so much power and using a basic antenna concept is not really an option. The solution will be a directed beam, bundling the energy into the direction of the user. Thus, no power will go to an area where it is not used and would be wasted. This technique is known in the Aerospace and Defense world since quite some time but with 5G will reach a much wider spread in the industry. Beside bundling energy, beamforming brings another advantage: User are separated by space, so a certain transmission block in frequency and time can be reused for a second user at a different position assuming the direction is separated wide enough. This improves the spectrum efficiency of the network and is obviously a great benefit to operators as they can serve more customers reusing same resources.

Massive MIMO (Multiple Input Multiple Output) will also be deployed in the sub 6 GHz bands in order to increase spectrum efficiency. Massive MIMO is a combination of MIMO and beamforming. Beamforming helps in the same way as for higher frequencies by reusing the same spectrum for different locations. On top, diversity gain from using the classic MIMO approach helps to improve the signal link similar to its use in 4G LTE.

## TRANSLATION TO COMPONENT REQUIREMENTS

As the signals get wider, the amplifiers in basestations as well as in user devices have to deal with the increased bandwidths. Digital pre-distortion (DPD) is optimizing the performance of the signal in-band and to reduce out-of-band emissions. For sub 6 GHz range, the common sense is that DPD will be deployed, for the mmWave range, it remains open. In-band, the error vector magnitude (EVM) improvement leads to higher data throughput enabling higher order modulations schemes up to 256QAM. Out-of-band, the lower leakage helps to reduce the interference, thus the signal-to-noise (SNR) ratio of the neighboring carrier improves. Bandwidths extensions can range from a factor of 3 to 10 due to DPD compared to the carrier bandwidth. Carrier aggregation will further extend the bandwidths. To cover for all this, amplifier companies are working towards very wide bandwidth coverage to span the high bandwidths and ideally cover multiple 5G bands in order to reduce the amount of different amplifiers in a front-end module.

As the number of different bands is increasing by including the 3.5 GHz area, the amount of filters, on mobile site typically SAW (Surface acoustic wave) for the lower frequency bands and BAW (bulk acoustic wave) for the higher frequency bands, will go up. Thus, all components needs to get smaller and more integrated to reduce footprint and cost. However, as filters are needed for the different bands, the number of filters will further go up per device.

On the base station side, GaN (Gallium Nitrite) technology will get into mobile wireless applications offering wider bandwidth within one amplifier. Higher energy density enables smaller devices to cover the same gain and reach the same output power. Again, this is a common technology for radar applications in the aerospace & defense sector, which will now get into mobile wireless applications. The new challenge is to linearize the behavior over a large range.

The biggest game changer will be the shift to beamforming. The system design of the RF frontends will differ significantly as well as the needed components. In the mmWave range, the typical antenna design will be a phased array antenna system with many elements for the base station. The higher the number of elements, the narrower the beam gets and the more efficient will be the generated RF power used. Obviously, the higher the number of elements the more complex the system gets. Ideally, every element connects to its own RF frontend including filters, switches and amplifiers. It is easy to understand that size will be a big concern driving the antenna elements.

A major challenge will be the importance of stability of the system. The amplifiers, filters and all involved components shall be very stable over time and temperature as drifts will have a direct effect of the ability to steer a beam clearly in a certain direction. Feedback loops with realtime monitoring will be implemented to control and offer ability to adjust the phases per path if needed.

Up to now, the common filter technology for base stations is the cavity filter. They are solid and stable over time and temperature. They can be easily tuned in production and withstand large RF power levels. But their size will be challenging in a phased array antenna system. As the RF level per path will go down while the number of antenna elements go up, the filter will not see such high powers any more thus different technologies can be introduced like ceramic filters or printed filters. This will enable new player in the market and may become a threat for common filter vendors.

Even so, space is at premium in hand held devices, it is expected they will include some form of beamforming. The integration of beamforming antennas into mobiles will pose an even more challenging issue. Antennas need to be placed in positions where the hand does not cover them for mmWave frequencies. Another concern will be the power consumption and integration of modules and components enabling for active beam forming on a mobile device. Beam switching may become an alternative using an approach similar to Butler matrix designs.

Obviously, an up to now unknown level of integration will come and be needed to enable the 5G designs in a small and cost efficient way.

## TEST REQUIREMENTS

Due to the increase in signal bandwidth, test signals must be realistic to show the truth performance. Typically wideband modulated signals are needed to characterize for examples amplifiers. Rohde & Schwarz offers with the vector signal generator R&S®SMW200A and the signal and spectrum analyzer R&S®FSW tools, which support an unrivaled signal bandwidth of 2 GHz up to 40 GHz RF frequencies without having to loop in external instruments to cover the high bandwidth.

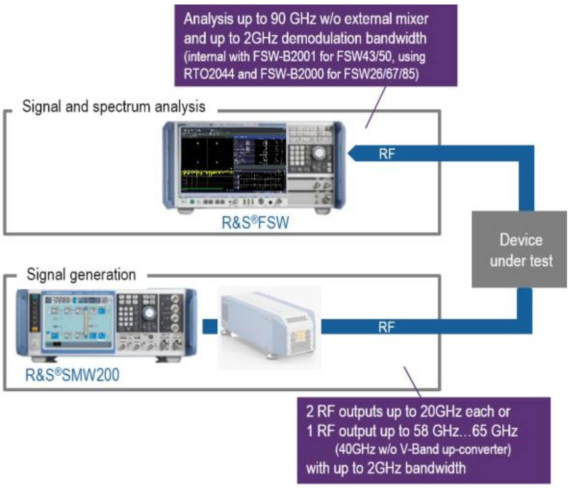


Fig. 2: Rohde & Schwarz 5G wideband solution

Another topic due to the high level of integration will be the accessibility of measurement planes on modules. Phased array antennas or other multi antenna structures will be molded together with the RF front-end (RFFE) modules. This leads to over the air (OTA) testing to verify RF performance and characteristics of integrated modules in addition to antenna verification. Rohde & Schwarz is the only test & measurement company offering far-reaching OTA solutions from antenna test software to different size shielded chambers offering full system level installations with RF test system and calibrated integrated antennas.

Fig. 3: Rohde & Schwarz mmWave OTA verification test system

## SUMMARY

5G is following a paradigm shift in its approach defining the new generation driven by target applications. Many of them lead to even more power consumption critical designs and a closer monitoring RF level budgets as with 4G. Going up to mmWave frequency ranges and extending the bandwidths to 100 MHz and more pushes technology of the components. In addition, beamforming will become standard and will drive the level of integration and miniaturization of the individual blocks for RF and mmWave frequency solutions.


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